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AQUATIC ECOSYSTEMS IN SEMI-ARID REGIONS

IMPLICATIONS FOR RESOURCE MANAGEMENT

Sponsored by
The National Hydrology Research Institute

THE RAWSON ACADEMY OF AQUATIC SCIENCE
L'ACADEMIE RAWSON DES SCIENCES DE L'EAU

27-30 August 1990
Saskatoon, Saskatchewan

Abstracts

91-02721/

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AUGUST 27-30, 1990

SASKATOON, SASKATCHEWAN

CANADA

ABSTRACTS OF PRESENTED PAPERS AND POSTER PAPERS

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AUTUST 27-30, 1990
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ABSTRACTS OF PRESENTED PAPERS

Adams, G. D.[1], A. Didiuk, D. Pochailo and K. Eskovich. [1]Canadian Vildlife Service, 115 Perimeter Road, Saskatoon, SK, S7N 0X4. **IMPACT OF DROUGHT AND LAND USE ON PRAIRIE POTHOLES IN THE ANTLER MUNICIPALITY, SASKATCHEWAN.**

In the Antler municipality, site of the Prairie Pothole Project, Saskatchewan Parks and Renewable Resources and the Canadian Wildlife Service are evaluating habitat management programs designed to counteract waterfowl habitat losses due to land use trends. Changes in wetlands were monitored from wet (1986) to dry years (1988-89) on 4800 prairie potholes mapped, digitized and surveyed on 57 km² of transects. High surface water levels in May 1987 were related to accumulations from high intensity rainfall events in 1985 and 1986. Declines in precipitation combined with high temperatures in 1987-88 left 86% of wetlands dry in May 1988. The proportion of wetlands impacted by agriculture showed negative correlations with wetland size, increasing from 25% in 1987 to 50% in 1989. Irreversible impacts to small prairie potholes may prevent future restoration of their water recharge and waterfowl habitat capabilities.

Arts, M. T.[1], and M. S. Evans[1]. [1]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5. **THE PREDICTIVE ROLE OF LIPID ENERGY RESERVES IN AQUATIC RESOURCE MANAGEMENT.**

Resource managers face the dilemma of how much to modify or manipulate specific attributes of the aquatic habitat in order to produce a desired effect (e.g. increased water clarity) without disrupting the flow of energy up trophic levels to economically important fish and waterfowl species. The effects of these perturbations on species demographics often occur too quickly (primary consumers/producers) or too slowly (fish/aquatic macrophytes) to be of much predictive value to resource experts. zooplankton however, strike a compromise between higher and lower trophic levels since generation times are short and animals are easily cultured. We demonstrate that seasonal patterns of energy reserves differ strikingly among zooplankton species in a saline and in a hypereutrophic prairie lake. In addition, we present a new optical method that provides direct information on the physiological status of individual copepods and propose that simple probabilistic models based on the distribution of energy reserves within individuals can be used to assess the effects of short- or long-term environmental manipulations.

Ashley, K. I.[1], B. Chan and K. Tsumura. [1]Fisheries Branch, Ministry of Environment, 2204 Main Mall, Vancouver, BC, V6T 1W5. **FISHERIES MANAGEMENT OF WINTERKILL LAKES IN SOUTHERN INTERIOR BRITISH COLUMBIA.**

Many of the small lakes in British Columbia's arid southern interior plateau region experience varying degrees of winter trout mortality due to a combination of natural high productivity, high oxygen depletion rates, shallow depths and extended periods of ice cover. Management options for maintaining recreational fisheries in these lakes include stocking with low oxygen tolerant species (Salvelinus fontinalis), stocking with large yearling rainbow trout (Oncorhynchus mykiss) to provide seasonal fisheries and the use of artificial circulation to maintain annual fisheries. Artificial circulation is used to prevent winterkill in lakes near electric power lines, however many lakes are too distant from power lines. A number of field trials have been conducted with photovoltaic powered circulation systems in an attempt to develop a suitable remote power source. An emerging management concern is the potential effects of global climatic change.

Barica, J.[1] [1]Lakes Research Branch, National Water Research Institute, Burlington, ON, L7R 4A6. **ECOLOGICAL STABILITY OF EUTROPHIC PRAIRIE LAKES.**

Due to high natural nutrient input from the drainage area (via groundwater and soil erosion) calculated from 3.3 to 25 $g/m^2/yr$ with very low N:P ratios (3-5:1), semi-arid climate with high solar energy input, most of freshwater and moderately saline prairie lakes are eutrophic to hypereutrophic, with heavy blue-green algal blooms dominating the lakes in the summer. High input of nutrients, shallowness, limited flushing and unsustainable primary production lead to seasonal perturbations of ecological stability resulting in severe dissolved oxygen depletion, consequent massive die-offs of fish populations and overall disruption of ecosystem integrity.

There are two major seasonal ecological instabilities occurring in hyperproductive prairie lakes of southern Manitoba and Saskatchewan:

1. Collapses of algal blooms and summerkill phenomenon: This disturbance takes place when the whole mass of the bloom (usually that of Aphanizomenon flos-aqual) suddenly dies and undergoes a rapid bacterial decomposition, resulting in complete oxygen depletion, generation of toxic unionized ammonia and eventually a massive fish-kill. the mechanism of this process was described and predictive models developed. It was observed that the algal collapse of various degrees of severity always occurred at the times of both water and air temperature drop. The weather, together with acute nutrient deficiency in the algal cells, appeared to trigger the algal bloom collapse.

2. Winterkill phenomenon: The shallow Prairie lakes are regularly subjected to six-month long periods of ice and snow cover, when excessive ice and snow cover prevents oxygen input from primary production and the atmosphere. Bacterial decomposition processes take over and consume available oxygen, which declines to critical levels, resulting again in fish mortalities (winterkill). This process was found to be controlled by the duration of the freeze-up, thickness of snow cover, initial dissolved oxygen levels prior to the freeze-up, and the mean lake depth. Models for prediction of this phenomenon were developed and verified.

It can be concluded that, unlike salinity and productivity, collapses of algal blooms and overall ecological stability are controlled primarily by meteorological factors, while the winter anoxia is a result of the continental semi-arid climate and topography. The critical borderline for algal bloom stability was estimated to be between 100-200 µg/L chlorophyll a, and the amplitude of its oscillation was suggested as a measure of ecological stability.

Bothwell, M. L.[1], G. Derkson[2], R. Nordin[3], and J. Culp[1]. [1]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5; [2]Environmental Protection Service, Vancouver, B.C.; [3]British Columbia Ministry of Environment, Victoria, B.C. **AN EFFLUENT HOLD BACK STRATEGY FOR CONTROL OF ALGAL PRODUCTION IN THE THOMPSON RIVER, B.C.: A CASE HISTORY OF WATER QUALITY MANAGEMENT.**

The main stem of the Thompson River is a nutrient-limited system in which the foodweb is primarily dependent on autotrophic, autochthonous production. Several months following the start up of a large kraft pulp mill in 1971, algal biomass in the Thompson River increased dramatically. While increased phosphorus loading was believed to be the primary reason for the elevated algal accumulation, populations of grazing inverte-brates were also depressed in the early 1970's. A strategy for low-flow winter hold back and tertiary treatment of municipal sevage initiated by the City of Kamloops in 1977 effectively cut P-loading by 60%. While algal biomass has declined in apparent response to this action, P-loading to the system over the last decade has been slowly rising because of increased production by the pulp mill. Quantitative studies of the relationship between areal algal biomass and ambient phosphorus concentrations make it appear unlikely that control of phosphorous alone was responsible for the reduced algal accumulations. Evidence indicating that the numbers of algal grazing invertebrates have increased dramatically in the last 15 years suggests that grazers may have played a large role in modifying the response of algal biomass to phosphorus in the Thompson River.

Boulton, A. J.[1], E. H. Stanley[1], S. G. Fisher[1] and P. S. Lake[2]. [1]Department of Zoology, Arizona State University, Tempe, AZ 85287; [2]Department of Botany and Zoology, Monash University, Clayton, 3168 Vic. Australia. **OVER-SUMMERING STRATEGIES OF MACROINVERTEBRATES IN INTERMITTENT STREAMS IN AUSTRALIA AND ARIZONA: CONTRIBUTIONS FROM "DOWN UNDER".**

Aquatic macroinvertebrates adopt physiological and/or behavioural strategies to avoid desiccation during dry periods in intermittent streams. Differential survival determines which biota are present when flow resumes and dictates the direction of subsequent succession. In two Victorian intermittent streams, 38 taxa (42% of all taxa collected during the dry period) sought refuge below the stream bed in the hyporheic zone (8 taxa), in crayfish burrows (6) or as resting stages in dry sediments in pools (24) and riffles (27). Most of these taxa were common in epigean samples collected after flow resumed. Preliminary data from a Sonoran desert stream indicates a richer hyporheos (at least 30 taxa) rarely found in epigean benthic samples. In two Australian intermittent streams, some stability of the epigean ecosystem to drying disturbances is apparently conferred by refugia "down under" whereas the limited overlap between the hyporheos and epigean benthos in a Sonoran desert stream implies that this refuge, although species-rich, contributes little to benthic resistance to drying.

Bowen, S. T.[1] and J. R. Carl. [1]San Francisco State University, Dept. of Biology, 1600 Holloway Avenue, Sans Francisco, CA 94132. **ARTEMIA POPULATION DIFFERENCES IN TOLERANCE OF LOW SODIUM/POTASSIUM RATIOS.**

The semispecies and allospecies within the Artemia franciscana superspecies are reproductively isolated in nature by adaptation to waters of different ionic composition. We briefly compare the ion ratios of the hypersaline habitats with the ionic adaptations of the populations (determined by laboratory viability experiments). We present new data on nine populations from Western United States and from Canada reared in culture media with Na/K molar ratios of 8 or >100. Increased Na reduces K-toxicity; the effect is due to increased concentration of sodium rather than increased osmolarity or ionic strength. We have designed an array of media pairs: in each pair, one medium is selective against many (but not all) populations; the control medium is permissive for all populations. These permit an estimate of the frequency of nonadaptive and adaptive ion tolerances and the extent to which components of a superspecies have tracked their environment in the Holocene.

Brock, J. T.[1], C. L. Caupp, T. J. Anderson, P. W. Lawson, and T. W. Cassidy. [1]Dept. of Biological Sciences, Idaho State University, Pocatello, Idaho, USA 83209. **SIMULATION OF RIPARIAN SHADE AND TEMPERATURE IN A NEVADA DESERT RIVER AND POTENTIAL EFFECTS OF CANOPY AUGMENTATION.**

Flows of the Truckee River (Nevada, USA) are regulated in part to optimize conditions for reproduction of the cui-ui (Chasmistes cujus), an endangered fish residing in Pyramid Lake. To enhance fish habitat with respect to temperature for the cui-ui and other species, augmentation of riparian vegetation along a portion of the 30-50 m wide river is planned in con-junction with a proposed flood control project. We developed a model that simulates riparian shade to aid in the identification of areas where tree plantings along a 10-km segment of the river would be most beneficial. Characteristics of the river channel and existing riparian vegetation were combined with solar geometry to estimate stream surface shade. Integrated measure-ments of light transmission and fisheye photographs of vegeta-tive cover provided data on the amount of solar radiation transmitted to the river surface through the existing canopy. Simulation results indicated that the shaded portion of the steam surface varies seasonally from 13% to 28% and that shade could be increased to a range of 26% - 54% after planted trees grew to a height of 15 m. The shade mode was linked to a calibrated temperature model that simulated water temperatures under various scenarios of riparian canopy augmentation.

Burns, B.[1]

Buskerud, S.[1] and L. Haertel. 332 Agricultural Hall, South Dakota State University, Brookings, SD 57007; [2]Department of Biology & Microbiology, College of Agriculture and Biological Sciences, South Dakota State University, Box 2207B, Brookings, SD 57007-0595. **PREDICTION OF WATER TRANSPARENCY AND PLANKTON SPECIES ABUNDANCE IN A MULTIBASIN PRAIRIE LAKE.**

Oakwood Lake (South Dakota) is a multibasin system showing upstream-downstream changes in nutrient loading, and with basin volumes varying from 0.16 to 6.68 x 10^6 m^3. Water transparency and abundance of phytoplankton, zooplankton and ichthyoplankton were sampled biweekly at 7 locations throughout the 1988 open water season. Predictive formulae were developed for water transparency, total biomass and individual species of phytoplankton and zooplankton by multiple regression analyses. Weather variables, basin size, nitrogen and phosphorus concentrations and other planktonic species present

were used as independent variables. Weather variables, phytoplankton and zooplankton density and basin size were all important predictors of water transparency. Zooplankton species present and weather variable were more important predictors of both total algal biomass and individual algal species abundance than were basin size or nitrogen or phosphorus levels. Algal species present were more important predictors of zooplankton species abundance than were weather variables, basin size or ichthyoplankton. Partitioning data into spring, early summer, and late summer seasons resulted in a higher percentage of variability predicted than when data from all seasons were combined. Separating plankton into species rather than using of total algal biomass or total zooplankton biomass as independent variables also resulted in a higher percentage of variability predicted.

Byrne, J. M.[1] [1]Coordinator, Water Resources Institute, University of Lethbridge, and Chair, Conference on Irrigation Research and Development in the 1990s, July 17-20, 1990, Lethbridge, AB, T1K 3M4.
IRRIGATION RESEARCH AND DEVELOPMENT IN THE 1990'S SUMMARY OF THE CONFERENCE AND WORKING GROUP REPORTS.

A major international meeting, Irrigation Research and Development in the 1990s conference, will be held in Lethbridge, Alberta, July 17-20, 1990. The meeting has a central objective of developing a unified statement on irrigation R&D directions into the next century. The statement, in the form of a conference report, will provide a working reference for policy makers, scientists and the farming community. There will be subcommittee reports on a number of separate issues, including on-farm irrigation, irrigation district/system management, irrigated agriculture strategies, soils, environmental interaction, climate variability/change and infrastructure R&D needs. Each of these reports will be integrated into the conference report. The final conference report will determine priorities in R&D for the next decade.

Irrigation is a vital component in the economies of semi-arid regions. Concerns over drought (throughout the 1980s) and forecast climate warming have resulted in increasing pressure for irrigation development in some areas. If these developments are to take place, cooperation with aquatic ecologists will be required to protect, and where possible, enhance, the aquatic environment.

Chambers, P. A.[1], E. E. Prepas, H. R. Hamilton and M. L. Bothwell[1]. [1]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5; [2]University of Alberta, Edmonton, AB; [3]HydroQual Consultants, Calgary, AB. **CURRENT VELOCITY AND ITS EFFECT ON THE GROWTH OF AQUATIC MACROPHYTES IN LARGE RIVERS ON THE CANADIAN PRAIRIES.**

Unlike most large rivers throughout the world, large rivers in the semi-arid region of the Canadian prairies (i.e. the South Saskatchewan, Assiniboine-Red and Missouri basins) have low flow rates (301 m^3/s annual mean), even though they drain in excess of 380,000 km^2. In these systems, aquatic macrophytes grow abundantly, particularly in reaches receiving increased nutrient loading as a result of sewage inputs. To determine the role of current velocity in controlling the growth of rooted aquatic plants in Canadian prairie rivers, a four-year study of natural macrophyte communities was undertaken in the Bow River, Alberta, Canada. The results showed that plant biomass decreased with increasing current velocity in the weed-bed over the range 0.01 to 1 m/s; at current speeds in excess of 1 m/s, aquatic macrophytes were rare. Transplant experiments conducted in the Pembina River, Alberta, Canada, in which Potamogeton pectinatus was grown in pails containing three sediments differing in texture at three sites with different current velocities, further demonstrated that biomass and shoot density were affected by both the direct effects of current velocity on metabolic rates and biomass accrual and its indirect effects on sediment nutrient concentrations. These results indicate that current velocity is an important factor controlling aquatic macrophyte biomass in flowing waters and suggest that for large, slow-flowing rivers, even a relatively modest increase in current velocity reduces the abundance of submerged aquatic plants.

Chrzanovski, T. E.[1] [1]Department of Biology, University of Texas at Arlington, Arlington, Texas 76019. **MICROBIAL PROCESSES IN A SOUTHWESTERN RESERVOIR.**

Lake Arlington (32°42'30"N, 97°12'30"W) is a mesotrophic, monomictic shallow reservoir. Epilimnetic temperatures vary annually between 7 and 35°C. Microbial studies in this lake have concentrated on elucidating factors that regulate planktonic bacterial populations and on quantifying rates of carbon flow through the microbial food web. Studies have centred on estimating phytoplankton production, bacterial secondary production, bacterial heterotrophic potential, phytoplankton-bacterioplankton coupled carbon flow, and rates of protozoan predation on bacteria. Rates of microbial mediated processes may be separated and characterized according to the winter-summer season shift. During winter months, microbial activity is depressed even though biomass is at the seasonal maximum. Indices

of microbial activity increase rapidly during early summer and remain high through lake holomixis in the fall. Increased cell metabolism occurs coincidentally with increased cell abundance. However, this relationship is not maintained as cell abundance falls in mid-summer due to predation pressure. These data suggest that microbial populations are functioning in a seasonally 'toggled' system (toggled off in winter, toggled on in summer) and that bacterial populations are regulated by balance of substrate supply and grazer activity.

Cushing, C. E.[1], W. L. Gaines[1], and E. G. Wolf[1]. [1]Pacific Northwest Laboratory, Richland, WA 99352. **PRIMARY AND SECONDARY PRODUCTIVITY IN COLD DESERT STREAMS.**

Measurements of primary production have been made in Rattlesnake Springs, and secondary production in Rattlesnake Springs, Snively Springs, and Douglas Creek, all located in southcentral Washington in the shrub-steppe region of the cold desert province.

Daily P_g and P_n rates averaged 8.7 and 0.9, 0.6 and 0.3, and 9.3 and 1.2 g $C \cdot m^{-2} \cdot d^{-1}$ for periphyton, watercress, and total community, respectively. Annual community P_g was 2700 g $C \cdot m^{-2} \cdot yr^{-1}$ and was highest for periphyton. Periphyton P_n (356 g $C \cdot m^{-2} \cdot yr^{-1}$) exceeded that of watercress. Community R was 2257 g $C \cdot m^{-2} \cdot yr^{-1}$, and was highest for periphyton.

Dipterans (midges and black flies) were the most productive taxa accounting for 40-70 percent of the total insect production. Production by collectors and detritivores was the greatest of all functional groups and trophic levels, respectively, in all study streams. Insects with rapid development times and multiple cohorts are very important in cold desert streams, and were major contributors to the total insect production. Insect production rates in our study streams ranged from 14 to 23 g $DW \cdot m^{-2} \cdot yr^{-1}$.

Dahm, C. N.[1], M. C. Molles Jr.[1], and M. T. Crocker[1]. [1]Department of Biology, University of New Mexico, Albuquerque, New Mexico 87131. **CLIMATE VARIABILITY AND STREAMS AND RIVERS IN SEMI-ARID REGIONS.**

Variability of mean annual precipitation in semi-arid regions tends to be greater than in more mesic areas. Global weather patterns linked to the El Nino/Southern Oscillation (ENSO) phenomenon are often a major causal mechanism for this variability. Streams and rivers in regions affected by ENSO phenomenon also reflect this variability with alternating periods of droughts and floods. The long-term hydrographs of two rivers in New Mexico, the Pecos and Gila rivers, demonstrate the strong correlation between ENSO conditions in the tropical Pacific Ocean and spring streamflow during snowmelt. Unusually high or low amounts of precipitation in the winter and spring may also affect flow responses of ephemeral and intermittent streams in semi-arid regions during the summer thunderstorm season. A large spatially intermittent

river, the Rio Salado, showed an inverse relationship between winter/-spring moisture and subsequent summer spates. Severe spates were much more common after antecedent dry periods. Linking a better understanding of hydrologic processes in semi-arid regions affected by the ENSO phenomenon to processing and biotic communities in riparian and stream ecosystems is a major goal of a new long-term ecological study we are initiating at the Sevilleta Long-Term Ecological Research (LTER) site in central New Mexico.

Davies, B. R.[1], J. H. O'Keeffe[2] and R. D. Walmsley[3]. [1]Freshwater Research Unit, Zoology Department, University of Cape Town, Rondebosch, South Africa; [2]Institute for Freshwater Studies, Zoology Department, Rhodes University, Grahamstown, South Africa; [3]Foundation for Research Development, Box 395, Pretoria, South Africa. **ATTRIBUTES OF SEMI-ARID RIVERS IN SOUTH AFRICA: SPATIAL AND TEMPORAL ASPECTS OF WATER MANAGEMENT.**

Semi-arid rivers are defined as allogenic systems in which at least 50% of the catchment receives less than 600mm mean annual rainfall, and in which the MAR:MAP ratio is less than 15%, but which always have some surface water along their whole length. Under this definition, all the rivers of Southern Africa, south of and including the Limpopo River are semi-arid, with the exceptions of some in drainage regions in the eastern Drakensberg Escarpment and in the western cape-fold mountains.

Since the main water demand areas do not correspond with the high rainfall regions of the sub-continent, the framework for water management has centred upon water storage and transfer from high rainfall-low demand regions (for example from Natal, Zululand and Lesotho) to the low rainfall-high demand regions (for example the central urban and industrial areas of the Transvaal). This has resulted in the over-regulation and over-utilisation of most rivers of the region. The combination of high effluent loads in rivers with low natural runoff and large impoundments acting as barriers to downstream flushing has resulted in some of the worst eutrophication and salinisation problems in the world (for example, Hartbeespoort Dam on the Crocodile River, and Laing Dam on the Buffalo River.

This paper addresses the consequences of unpredictable flow variability on the riverine biota and on management planning and water allocation. Past management has concentrated on storage, possibly in inappropriate places (for example, large dams on the Orange and Pongolo rivers), while present policy concentrates on water transfer schemes which are extremely costly and which take little cognizance of future developments in donor areas. Both of these options offer only short-term solutions and we suggest that ultimately, education, recycling, correct pricing and water quality mixing - while very expensive are the only economically and environmentally viable routes for future water management.

Dinsmore, P.[1] and E. E. Prepas[1]. [1]Department of Zoology, University of Alberta, Edmonton, AB, T6G 2E9. **EVALUATION OF TRENDS IN PROFUNDAL MACROINVERTEBRATE DENSITIES, BIOMASS AND DISTRIBUTION IN A LAKE UNDERGOING HYPOLIMNETIC OXYGEN INJECTION.**

Amisk Lake, located 175 km northeast of Edmonton, Alberta is typical of many deep eutrophic lakes in that the hypolimnion becomes anoxic during periods of stagnation. Conditions in the deep profundal regions limit or exclude macrobenthic communities. An aeration project involving liquid oxygen commenced in June 1988, the goal of which is to increase hypolimnetic dissolved oxygen concentrations and thus increase fisheries habitat. The macrobenthic communities of the aerated north and non-aerated south basins of Amisk Lake were monitored during the ice-free seasons of 1988 and 1989. Preliminary results indicate that hypolimnetic oxygen injection may have enhanced chironomid survivorship and colonization in the treated north basin of Amisk Lake.

Ferrington Jr., L. C.[1] [1]Kansas Biological Survey, Department of Entomology, Foley Hall, West Campus, University of Kansas, Lawrence, KS 66047-2906. **THE SIGNIFICANCE OF CAPILLARY FRINGE HABITATS TO AQUATIC INVERTEBRATE COMMUNITIES OF RIVERS IN THE CENTRAL PLAINS OF THE UNITED STATES.**

Invertebrates form the basis of the food web for many prairie fishes and migratory waterfowl. Management efforts directed at fishes and migratory waterfowl must therefore be based upon consideration of invertebrate communities in order to be successful. Our understanding of the structural and functional characteristics of invertebrate communities in pristine streams and rivers of the Central Plains is, however, quite meager at present.

Over the past century regulation of major river systems in the Central Plains by damming and channelization has significantly changed the physical structure and discharge characteristics of the rivers. Consequently, there are few remaining stretches of river where pristine conditions exist for research on unaltered invertebrate communities. In this presentation I will provide a historical reconstruction of the attributes of the Arkansas River prior to the 1880's, and before significant regulatory activities occurred along its basin and flood plain in western Kansas. The reconstruction will serve as a model for understanding the spectrum of habitat conditions available to aquatic invertebrates in unaltered riverine systems. It will also serve as a backdrop for formulating management criteria.

Based upon the reconstruction I will argue that capillary fringe habitat was a significant component of the habitat spectrum available to aquatic invertebrates before rivers were regulated. I will next describe the characteristics of capillary fringe habitats, and present

data from recent research efforts to determine the structural and functional significance of invertebrate communities inhabiting capillary fringe in the Cimarron River and other sand-bottom rivers in Kansas. I will speculate on the significance of invertebrate production in capillary fringe habitats with regard to fish communities and migratory waterfowl, and end with comments regarding management of surface waters and surrounding riparian zones in order to conserve capillary fringe habitats for invertebrate production.

Field, K. M.[1] [1]Department of Zoology, University of Alberta, Edmonton, AB, T6G 2E9. **THE IMPACT OF HYPOLIMNETIC OXYGEN INJECTION ON THE ZOOPLANKTON COMMUNITY OF A EUTROPHIC BOREAL LAKE.**

Amisk Lake is a deep eutrophic lake located in the boreal forest of central Alberta, Canada. During summer stratification, the hypolimnion has historically been anoxic by mid-summer. Since June 1988, oxygen has been injected into the hypolimnion of the north basin year round, to elevate dissolved oxygen levels. Zooplankton samples were collected from the treated (north) and reference (south) basins during the open-water seasons of 1988 and 1989, and during the winters of 1989 and 1990. This study examined the effects of increased hypolimnetic oxygen concentrations on the vertical distribution, biomass, relative abundance, and size structure of the zooplankton community. Improved oxygen concentrations in the treated (north) basin had an immediate impact on the distribution of pelagic zooplankton populations.

Fisher, S. G.[1] [1]Department of Zoology, Arizona State University, Tempe, AZ 85287. **A MULTIPLE-SCALE APPROACH TO NATURAL AND ANTHROPOGENIC CHANGE IN STREAMS OF ARID LANDS.**

Streams in hot deserts of the world represent an extreme case of the interaction of arid lands and aquatic resources. To understand the functioning of desert streams and rivers requires a multi-scale perspective which incorporates a spatial hierarchy ranging from microscopic particles to entire watersheds and a temporal framework encompassing several orders of magnitude. Stream structure and function can then be viewed as a frequency distribution of system states within this four-dimensional space. Both basic and applied research should take cognizance of this view; basic research to establish the boundaries of the system and applied work to insure that management minimizes excursions out of this space. Stream response to channelization, flow regulation, cattle grazing, and introduction of exotics will be illustrated in this framework.

Fuller, G.[1] [1]University of Regina, Regina, SK. **WATER DEVELOPMENT APPEAL PROCEDURES.**

Some means of appealing water development decisions other than through the courts is required because the courts are generally costly and slow. Often some form of water appeal board, functioning like a lower court, is empowered to make decisions regarding water related problems. The decisions made by water appeal boards can have a considerable influence on water resources management within their jurisdiction. As a result of this influence, appeal boards and their procedures must be chosen carefully so that individual appeal board members from various segments of society are able to make informed and independent water resources decisions. This paper provides some suggestions regarding the operation of water appeal boards that would contribute to the wise use of our limited water resources in this semi-arid region.

Gaudet, C. L.[1] and J. T. Hoenig[1]. Inland Waters Directorate, Environment Canada, Ottawa, ON. **MITIGATION: MEANING AND APPLICATION IN SUSTAINING AQUATIC ECOSYSTEMS IN SEMI-ARID REGIONS; SOME CASE STUDY EXAMPLES FROM THE CANADIAN PRAIRIES.**

In theory and in practice, the term mitigation appears to be open to interpretation and has been applied with inconsistency in meaning and in approach. Recent successful environmental challenges in federal court resulted in a more rigorous application of the federal Environmental Assessment and Review Process. This has raised questions about the meaning of mitigation as used in the 1984 Environmental Assessment Guidelines Order now that the Order carries the weight of law. With reference to case studies from semi-arid regions, this paper examines the meaning and nature of environmental mitigation and attempts to provide a clearer indication of its role in the practice of environmental assessment.

Gibson, K. S.[1], P. A. Chambers[2] and E. E. Prepas[1]. [1]Department of Zoology, University of Alberta, Edmonton, AB, T6G 2E9; [2]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5. **THE ROLE OF CURRENT VELOCITY AND SEDIMENT COMPOSITION IN DETERMINING POREWATER CHEMISTRY IN AN UNREGULATED RIVER IN ALBERTA.**

To determine the factors controlling the variability of sediment-porewater concentrations, in situ studies were conducted in the Pembina River, Alberta, Canada. The Pembina River is a major tributary to the Athabasca River and is part of the Peace-Mackenzie system.

During 1988 and 1989, phosphorus, nitrogen, iron and calcium concentrations in the porewater were compared with those in the sediment-bound pool, for three sites differing in sediment composition (cobble-clay, sand or silt-clay) and current velocity (0.64, 0.33 or 0.13 m/s; May-October average, 1988). Preliminary analysis suggests that temporal variation in porewater chemistry is related to sediment chemistry and current velocity rather than open-water chemistry. These results yield baseline values for phosphorus and nitrogen dynamics in northern rivers. These are important in view of the proposed increased industrial development in the Peace-Mackenzie river system.

Glozier, N. E.[1], J. M. Culp[2], and G. J. Scrimgeour[1]. [1]Department of Biological Sciences, University of Calgary, Calgary, AB; [2]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5. **COMPARISON OF HABITAT USE BY A LOTIC MINNOW IN TWO SEMI-ARID STREAMS: IMPLICATIONS FOR INSTREAM FLOW ASSESSMENT.**

Habitat suitability curves for prey species of salmonids can be used in conjunction with instream flow incremental models to predict food availability for salmonids. Often this is done by applying habitat suitability curves of trout prey from other rivers, thereby making the assumption that these curves are species-specific and do not differ among populations in different river systems. To test this hypothesis, we compared habitat suitability curves of a minnow prey of rainbow trout, the longnose dace (Rhinichthys cataractae), in Jumping-pound Creek, Alberta (mean annual discharge = 1.7 m^3/s) with the habitat occupied by dace in the larger Thompson River, British Columbia (mean annual discharge = 280 m^3/s). In Jumpingpound Creek, dace inhabited gravel and pebble substrates in shallow (mean depth = 18 cm), slow water (<20 cm/s). Dace in the Thompson River used cobble substrates in fast (> 80 cm/s), deep (<40 cm) riffle areas. Thus, the habitat requirements of longnose dace were not static among systems and, in fact, showed minimal overlap in habitat use between rivers. More generally this indicates that habitat suitability curves of salmonid prey can be affected greatly by local abiotic and biotic conditions.

Guerrero, M. C.[1], B. Vidondo, B. Martinez, M. L. Pascual. [1]Departamento de Ecologia, C-XV, Facultad de Ciencias, Universidad Autónoma de Madrid, 28049 Madrid, Spain. **THE CHIPRANA SALINE LAKE (ZARAGOZA, NE SPAIN) AND ITS COMMUNITIES OF PHOTOTROPHIC BACTERIA.**

The Chiprana saline lake, located in the Northeast of Spain, in the Ebro river basin, is the only permanent and deep water (5 m) saline ecosystem in Western Europe. With a total surface of about 0.31 Km^2 presents crenogenic meromixis, its range of salinity varied along 1989 from 53 to 73‰ TSD, and its ionic composition is

sulphated-magnesic. In the monimolimnium, of higher salinity than the rest of the water column, occurs oxygen depletion and increase of hydrogen sulphide together with the presence of light. These conditions determine the existence of anoxygenic phototrophic bacteria at this stratum. On the other hand, overlaying dispersal areas of the sediments of moderate slope, and less than 1 m. depth, it can be found laminated communities, the so called microbial mats.

Approaches realized with spectroscopy and optic and electronic microscopy have demonstrated the dominant species composition and structure of both planktonic and benthic communities.

Haertel, L.[1] and W. L. Tucker. [1]South Dakota State University, Biology Department, Brookings, SD 57006. **EVALUATION OF PLANKTON SPECIES RELATIONSHIPS BY MULTIPLE REGRESSION ANALYSIS.**

Multiple regression of lake phytoplankton and zooplankton data can provide a useful tool to predict species relationships. Multiple regression is inexpensive and can be performed for each lake, and it avoids the environmental risks of lake biomanipulation. It also avoids the artificiality of testing one factor at a time and eliminating important proximal or ultimate controlling factors in enclosure experiments. Assuming that statistically significant relationships between dependent and independent variables predict actual interactions in lake systems, regression analyses indicate that no two phytoplankton species interact with zooplankton species and physical and chemical variables tested in exactly the same way, supporting the multidimensional niche. When different lakes are compared, the same species does not interact with other variables in exactly the same way substantiating the problems involved in applying experimental results from one lake to different lakes. Results of multiple regression analyses from 6 prairie lakes are compared. Independent variables used for prediction of phytoplankton species are weather variables, nitrogen, phosphorus and silicon concentrations, and major zooplankton species present. Independent variables used for prediction of zooplankton species abundance are weather variables, phytoplankton species present, and when available, ichthyoplankton species present.

Hamilton, H. R.[1] and R. A. McDonald. [1]HydroQual Canada Ltd., #380, 4500-16 Ave. N.W., Calgary, AB, T3B 0M6. **PROJECTED WATER QUALITY CONDITIONS FOR THE RAFFERTY AND ALAMEDA RESERVOIRS.**

Major water quality issues with respect to reservoir development in semi-arid regions include salinization, high nutrient levels, thermal regime and potential for summer hypolimnetic or winter oxygen depletion. On behalf of the Souris Basin Development Authority, the effect of long term (>20 year) hydrologic patterns on reservoir salinity and nutrient regimes were simulated with the computer model

WQPM. Then empirical methods were used to predict stratification potential and oxygen depletion on an annual basis. Results indicate Alameda Reservoir will stratify, and be moderately productive. The hypolimnion should provide a cool water zone with sufficient oxygen to satisfy water quality criteria for trout. Due to its longer water residence time and shallower depth, Rafferty Reservoir will have a higher salinity level, should not stratify on a regular basis and will be more biologically productive.

Hammer, U. T.[1] and S. H. Hurlbert[2]. [1]Department of Biology, University of Saskatchewan, Saskatoon, SK, S7N 0W0; [2]San Diego State University, San Diego, CA 92182-0057. **IS THE OCCURRENCE OF ARTEMIA SALINA L. MEDIATED BY SALINITY TOLERANCE OR THE PRESENCE OF PREDATORS IN LOWER SALINITY WATERS?**

Brine shrimp (Artemia salina L.) are not normally found in saline lakes with less than 50 gL^{-1} salt and absent from some lakes of higher salinity. The Salton Sea (40 gL^{-1}) and Big Quill Lake (up to 80 gL^{-1} salinity) do not have brine shrimp populations. Filtered Salton Sea water (35 um mesh) and Big Quill Lake (76 um) was used to grow Artemia salina to maturity both from eggs (cysts) and ovoviviparously. In unfiltered water Salton Sea water Cyclops dimorphus (Kiefer) and Trichocorixa reticulata (Guerin-Meneville) prevented/restricted the survival of newly hatched brine shrimp. Similarly, Diaptomus connexus Light and Onychocamptus mohammed (Blanchard & Richard) prevent the survival of young brine shrimp in Big Quill Lake water. In the latter lake, the common Trichocorixa verticalis interiores Sailer could also play a role in preventing the establishment of brine shrimp populations.

Healey, M. C.[1] [1]Westwater Research Centre, University of British Columbia, Vancouver, BC, V6T 1W5. **TOP DOWN STRUCTURING OF AQUATIC FOOD WEBS BY LARGE PREDATORY FISHES.**

Lakes in semi-arid climatic zones of Canada have a relatively depauperate fish fauna. Lakes in this zone that are large enough to support large pisciverous fishes have a biotic community that is characterized by a high number of trophic levels, high levels of omnivory that extends beyond adjacent trophic levels, jagged biomass spectra, and donor controlled dynamics. These characteristics are illustrated by reference to lakes in the southern interior of British Columbia and in southern Alberta. I hypothesize that the large predaceous and long lived fishes are the dominant force structuring these communities. The characteristics mentioned above are, in some respects, inconsistent with predictions of modern food web theory.

Bochbaum, G. S.[1] and F. D. Caswell[1]. [1]Canadian Wildlife Service, 501 University Cr., Winnipeg, MB. **EFFECTS OF CLIMATE CHANGE AND AGRICULTURAL PRACTICES ON PRAIRIE DUCKS.**

Analysis of vetland basins in the prairie parkland region shov a dramatic decrease in vetland area available for waterfovl. From 1979 to 1988 the number of vetland basins declined by 56 percent. Synergistic effects between drought and agricultural alteration of vetlands have further eroded their productive capability. During the drought of the eighties in excess of 40 percent of the vetland basins and 80 percent of their associated margins were impacted by agricultural activities. Waterfovl populations have declined by 50 percent from 1979 to 1988 in association vith vetland loss. Certain species such as the pintail were more severely impacted, declining by 88 percent. Projected changes in temperature and moisture suggest that further losses of vetlands and vaterfovl are imminent. Displacement of vaterfovl northvard during periods of drought can be expected although production in the northern areas may not compensate for losses in the prairie parkland region. These vetland losses in the productive prairie parkland region are unlikely to be replaced by increased production further north.

LaBaugh, J. W.[1] and G. A. Swanson[2]. [1]U.S. Geological Survey, Lakewood, CO; [2]U.S. Fish and Wildlife Service, Jamestown, ND. **CHANGES IN CHEMICAL CHARACTERISTICS OF WATER IN SELECTED WETLANDS IN THE COTTONWOOD LAKE AREA, ND 1979-89.**

Five wetlands that were chemically different from one another (<300 to >20,000 uS/cm) were the subject of detailed hydrological and chemical studies during an 11 year period. Two seasonal wetlands either were dry or only contained water for several weeks in the spring during dry years (1980-81, 1985, 1988-89). These wetlands contained water for several months before becoming dry in late summer in a vet year (1987) when vater types changed (K HCO3 to Ca HCO3 and Ca SO4 to Mg SO4). Water levels in three semipermanent wetlands were highest in 1987 and lovest in 1988 and 1989, and one of these wetlands became dry in both 1988 and 1989. Two semipermanent wetlands had the most pronounced seasonal change in specific conductance during dry years, without any change in water type (Mg SO4 and Na SO4) during the study, but the other semipermanent wetland had larger changes in specific conductance during dry years, without any change in water type (Mg SO4 and Na SO4) during the study, but the other semipermanent wetland had larger changes in specific conductance during some vet years than during some dry years, and a change in water type occurred in 1989 (Mg HCO3 to Mg SO4). This study indicated that changes in chemical characteristics of water in wetlands in response to changes in hydrologic conditions were not consistent among wetlands in close proximity to one another.

Last, W. M.[1] [1]Department of Geological Sciences, University of Manitoba, Winnipeg, MB, R3T 2N2. **SALT LAKE PALEOLIMNOLOGY IN THE NORTHERN GREAT PLAINS: THE FACTS, THE FEARS, THE FUTURE.**

The Facts: The Great Plains contain many closed lacustrine basins. Because of the great diversity in lake types, brine chemistries, and depositional processes, the sediments in these basins offer a tremendous opportunity to study past environmental conditions in the region.

The Fears: Despite the sensitivity of these deposits to environmental change, interpreting the records in terms of paleoclimate, hydrology, and chemistry is fraught with difficulty. Factors that complicate these interpretations include: diagenesis of the evaporites, postdepositional physical disruption of the sediments, and a lack of proper understanding of the depositional processes operating in lakes of this type.

The Future: Notwithstanding the problems, the sediments of these basins provide the best and, in some cases, only record of past environmental conditions in this semi-arid region.

Mackay, J. R.[1] [1]Department of Geography, The University of British Columbia, Vancouver, B.C., V6T 1W5. **LAKE STABILITY IN AN ICE-RICH PERMAFROST ENVIRONMENT: EXAMPLES FROM THE WESTERN ARCTIC COAST.**

The wetlands of the western Arctic coast are an important habitat for migratory waterfowl, in some places for fish, and a potential area for gas and oil production within the next decade. Although 20 to 40 percent of the surface are is in lakes, both precipitation and temperature are low and impermeable permafrost occurs at depth. Lake development since Late Wisconsinan deglaciation has resulted primarily from the interplay of three main factors: climate warming followed by cooling; the presence of ice-rich permafrost at depth; and ice wedge growth accompanied by peat accumulation. During the post-glacial warming period of about 11,000 to 8,000 BP the thaw depth increased and thaw bulbs enlarged beneath water bodies deeper than the winter ice thickness. Wherever deepening thaw bulbs encountered ice-rich permafrost, the release of excess water caused ground subsidence and lake enlargement. Many of the existing lakes probably formed during this period. During the cooling trend commencing about 7,000 BP ice wedge growth, inactive during the warm period, was renewed. Peat accumulation, together with the volumetric displacement caused by the growth of ice wedge ice, elevated the ground surface and increased the ice content of the upper several metres of permafrost. Ice wedges, at low points of lake closure, then provided easily erodible channels for lake drainage. As a result, probably more than 5,000 lakes have drained in whole or in part, usually via ice wedge systems, within the past few thousand years. The present rate of lake drainage averages

one to three lakes per year. Consequently, the total lake area for the past few thousand years has been decreasing, while lakes have been becoming fewer, smaller and shallower. Innumerable lakes are now in a state of conditional instability where a slight environmental change, whether natural (e.g. climatic) or human-induced, could lead to either lake drainage or thaw lake enlargement.

MacLeod, D. L.[1] [1]Senior Vice-President, Saskatchewan Water Corporation. **WATER RESOURCE MANAGEMENT PROBLEMS AND CONFLICTS IN SEMI-ARID ENVIRONMENTS.**

Saskatchewan is a province characterized by diversity of climate, topography and other natural features including its water resources. The southern part of the province in particular can be classified as semi-arid with inadequate precipitation and excessive evaporation. As a result, water managers must continually walk a fine line between allocation of water to meet the needs of consumptive users and retention of water for non-consumptive uses. The increasingly competitive forum in which scarce water resources are managed means that it is necessary to look seriously at all the demands to ensure that they are legitimate, and that the best use is being made of the resource. Compounding the management problems are ever-increasing demands for environmental inputs and sustainable development considerations. In such a forum, tough decisions are required on the priorities which should be placed on the needs of people as opposed to the demands made on behalf of the "natural" environment.

McKee, M. H.[1] and F. J. Wrona[1]. [1]Department of Biological Sciences, Division of Ecology (Aquatic Research Group), University of Calgary, 2500 University Drive NW, Calgary, AB, T2N 1N4. **MOSQUITO BIOLOGICAL CONTROL USING TURBELLARIAN PREDATORS.**

Classical biological control theory, derived primarily from predictions of Nicholson-Bailey host-parasitoid models, emphasizes aspects of predator biology that result in a low stable equilibrium abundance of the pest. Consequently, certain biological and ecological attributes have been accepted as necessary requirements for suitable biocontrol agents, which preclude the use of generalist predators. However, with Murdoch et al.'s (1985) challenge of the low stable equilibrium concept, there is now recognition of a role for generalist predators in biological control. The Turbellarian predator, Dugesia tigrina Girard (Tricladida) is presently under study by our lab as a potential control agent of larval mosquito populations. Turbellaria, particularly members of the Tricladida, display a highly aggregated spatial dispersion which may effect feeding behaviour and attack rates. Laboratory experiments investi-gating the functional response of Dugesia revealed a Holling's Type II relationship with Daphnia and a Type IV with mosquito larvae. Increasing predator group

Murphy, T.[1], I. Gray[2], C. McKean[3], Phil Manning[1], Annette Moller[1]. [1]National Water Research Institute, 867 Lakeshore Rd., Burlington, ON, L7R 4A6; [2]Business Administration, McMaster University, Hamilton, ON, L8S 4K1; [3]British Columbia Ministry of Environment, Parliament Bldgs., Victoria, B.C., V8V 1X5. **SEDIMENT STUDIES IN THE INTERIOR OF BRITISH COLUMBIA.**

Chain Lake is an eutrophic lake in the dry interior of British Columbia. Much of the phosphorus loading enters the lake in springs that drain undeveloped mountains. The rocks are rich in phosphorus minerals such as apatite. Another source of eutrophication is the release of phosphorus from the sediments in midsummer. Approximately 60% of the iron in sediments deeper than 20 cm is pyrite; thus, the sediment's ability to retain phosphorus is weak. Phosphorus appears to have moved up the sediment producing relatively high surface concentrations of phosphorus; however, several peaks of phosphorus are present deeper in the sediments.

Diatom studies of a 10 metre long piston core indicates that the lake has usually been eutrophic. Immediately after the Mazama ash layer, the lake was dominated by diatoms that indicate low productivity. Also, there have been periods when winter diatoms (Melosira islandica) have dominated the lake. The occasional dominance of the diatom Fragilaria leptostauron indicates that there were times when the lake level was low and the climate was presumably drier. Corresponding sediment layers have relatively high concentrations of phosphorus.

The sediments are a diatomaceous ooze (20-85% silica). The sedimentation rate in the surface 1.5 m is approximately 0.7 cm/year. the surface 2.8 m of sediments have a high water content (>90%) and the surface metre of sediments can be easily pumped by a simple trash pump and pipeline that was built for $10,000. Sediments were removed at a rate of 16 m^3 an hour.

For this very productive 44 hectare lake, approximately 11 days a year of sediment pumping would be required to maintain the lake volume. Dredging all of the lake to suppress sediment release of phosphorus would take six to eight years of dredging 100 days a year to remove the surface 30 cm of phosphorus rich sediment.

Peterka, J. J.[1] [1]Zoology Department, North Dakota State University, Fargo, ND 58105. **SALINITY AND FISH REPRODUCTION IN DEVILS LAKE, ND.**

We documented salinity levels at which reproduction of fishes occurred in the sodium-sulphate waters of the Devils Lake chain of lakes. Fresh waters of 700 mg/l (TDS) enter the chain from the west via Big Coulee. Maximum salinities of 10,000 mg/l occur in East Devils Lake at the eastern end of the chain. Northern pike reproduction occurs only in Big Coulee and upper drainages where salinities

size produced an initial increase in per capita prey mortality, followed by a marked decrease when Dugesia group size exceeded 4 individuals/-treatment. The significance of predator group size-related effects on the control of mosquito populations will be discussed within the context of general biological control theory.

Melville, G. E.[1] [1]Aquatic Biology, Saskatchevan Research Council, 15 Innovation Blvd., Saskatoon, SK, S7N 2X8. **POPULATION AND BEHAVIOURAL RESPONSES OF VERY YOUNG WALLEYE (STIZOSTEDION VITREUM) TO SELECTED CRUSTACEAN ZOOPLANKTON DIETS: AN EXPERIMENTAL STUDY.**

Very young planktivorous fish of many species suffer high mortality rates in natural and seminatural systems. The cause of high mortality is often attributed to starvation. In this study, walleye survival through the first four weeks of life was 50% on a diet of Diaptomus sanguineus in artificial pools, double that (21%) on a diet of Daphnia pulex. Young juvenile walleye selected far more Diaptomus as prey than Daphnia at high total prey densities in laboratory experiments. The functional response for walleye fed Diaptomus reaches a plateau, but the curve for juvenile Daphnia exhibits a pronounced drop above 30 animals L^{-1}. Behaviour sequence observations indicate that the young walleye select Diaptomus over Daphnia of similar size, because Daphnia have a tail spine which sticks in the food passage of the fish. Predator-prey morphologies must be considered with respect to fish food selection, as well as nutritional, behavioural and other aspects. These results are important in understanding the factors controlling young planktivorous life stages of fish populations in both natural and fish culture systems.

Muralidharan, S.[1] [1]BNHS Ecological Research Centre Bharatpur 321 001 India. **ORGANOCHLORINE RESIDUES IN THE EGGS OF A FEW COLONIAL WATERBIRDS BREEDING AT KEOLADEO NATIONAL PARK BHARATPUR, INDIA.**

BHC, DDT, heptachlor and endosulfan in eggs of eight species of colonial waterbirds were measured. The G. mean of DDT was higher in eggs of Phalacrocorax fuscollis, Ardea cinerea and Mycteria leucocephala (0.8033, 0.7618, 0.6659 ppm, wet weight respectively) than that of other species. Eggs of Anhinga rufa and A. alba contained more BHC (0.4919, 0.4511 ppm respectively) than did the eggs of other species. Heptachlor residue in Platalea leucorodia (7.373 ppm) and A. cinerea (5.9383 ppm) was detected in all species. Barring a few cases, test of significance (t) ($P<.05$) between pesticide concentration in eggs of different species showed significant variation, whereas such phenomenon was not seed between species. Relationship between pesticide residue levels, egg shell thickness and resulting effects within the study area are discussed.

long water residence times (3 to 22 yr), are moderate-sized (A_o 1 to 10 km^2) and have hard water (alkalinity 3 to 4 meq/L). On an annual basis, P return from the bottom sediments is the major source of P (>75%) to the epilimnion of these four lakes. Thus management of surface water total P (TP) concentrations must focus on sediment-water interactions. Over the past four years two hypereutrophic hardwater lakes have been treated with lime ($CaCO_3$ and $Ca(OH)_2$) to reduce chlorophyll a and TP concentrations. In both treated lakes, TP and chlorophyll a concentrations have been reduced substantially in the years following the initial treatments. In this paper, we examine changes in annual flux of P from the bottom sediments of the lime-treated lakes.

Prompoj, W.[1], P. A. Chambers[2] and E. E. Prepas[1]. [1]Zoology Department, University of Alberta, Edmonton, AB, T6G 2E9; [2]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5.
PHOSPHORUS DYNAMICS IN THE BOTTOM SEDIMENTS IN RELATION TO THE ABUNDANCE OF AQUATIC MACROPHYTES IN A PRAIRIE RIVER.

Increased nutrient loading from sewage inputs has resulted in abundant growth of aquatic macrophytes in many prairie rivers. To determine the impact of open-water nutrient loading on sediment phosphorus (P) concentrations and, ultimately, aquatic macrophyte abundance, open-water and porewater (sediment-interstitial) samples were collected 9 times over the summer (May-September, 1989) and analysed for soluble reactive phosphorus (SRP), calcium, ferrous iron, and dissolved oxygen (DO) concentrations for five sites on the South Saskatchevan River: one site upstream and four sites downstream of a sevage treatment plant (three weed-free sites and two sites in weed-beds). Current velocity and sediment-exchangeable P were also measured. Porewater SRP concentrations varied as much as 100 fold over the summer, they were not related to open-water chemistry or current velocity but, instead, were related to porewater DO concentrations ($P<0.05, r=0.33$), at all five sites. Our results suggest that, over the summer months, aquatic macrophytes are capable of modifying the chemistry of the bottom sediments. Our study has important implications for aquatic weed control in prairie rivers -- aquatic macrophyte growth will be difficult to predict from nutrient loading (sewage inputs) into the rivers, since the P pool used by rooted aquatic-plants (i.e. porewater SRP) is not immediately related to open-water chemistry.

are about 700-1,000 mg/l. No northern pike reproduction occurred in 1988 or 1989 because of low or no flow in Big Coulee. Bullhead reproduction is restricted to Sullys Bay where ground water seepage reduces salinities to 1,000 mg/l. Yellow perch, white bass and black crappie reproduced in salinities of 2,000-3,000 mg/l. Salinities of >5,000 mg/l were high enough to restrict natural reproduction of game fishes, but not of fathead minnows and brook sticklebacks. Sticklebacks were the only fishes to reproduce in East Devils Lake. In the late 1800s, water salinities of 8,000 mg/l in Devils Lake apparently prevented reproduction of all fishes except for fathead minnows, brook sticklebacks and northern pike, the only fishes in the lake; northern pike reproduction was dependent on flows in Big Coulee.

Poiani, K. A.[1] and W. C. Johnson[2]. [1]Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061; [2]Head and Professor of Forestry. Horticulture, Forestry, Landscape & Parks Department, South Dakota State University, Box 2207-C, Brookings, SD 57007-0996. **RESPONSE OF PRAIRIE WETLANDS TO CLIMATE CHANGE: A SPATIAL SIMULATION MODEL.**

A spatially-defined model of a semi-permanent wetland in south central North Dakota was constructed. A hydrologic component estimates seasonal and yearly water levels based on potential evaporation, runoff, rainfall, and leakage. Wetland basin elevations and their corresponding topographic coordinates are converted into a computer-readable matrix where each cell represents a known area on the ground. The amount and distribution of emergent cover and open water are modeled using a Geographical Information System (GIS). The distribution of cover and water is determined from water levels and the life history characteristics of the dominant plant groups.

Cover/water distribution maps of the wetland were produced for about a decade (1980-89). Accuracy of the model was evaluated by comparing simulated results to actual distributions from aerial photos. Potential changes in emergent cover and open water due to a global warming were assessed using predicted temperature and precipitation values expected with a doubling of atmospheric carbon dioxide.

Prepas, E. E.[1], T. P. Murphy[2], J. Babin[3] and P. J. Curtis[1]. [1]Zoology Department, University of Alberta, Edmonton, AB, T6G 2E9; [2]National Water Research Institute, P.O. Box 5050, Burlington, ON, L7R 4A6; [3]HydroQual Canada Ltd., 4500 - 16th Ave. N.W., Calgary, AB, T3B 0M6. **THE IMPACT OF CALCIUM ADDITIONS ON SEDIMENT-WATER PHOSPHORUS DYNAMICS IN HARDWATER PRAIRIE LAKES.**

Detailed phosphorus (P) budgets have been constructed for four lakes in central Alberta. These lakes range from mesotrophic to hypereutrophic, shallow to relatively deep (z 4.5 to 14.4 m), have

R. Schutzman, R.[1] Saskatchewan Environment and Public Safety, 3085 Albert St., Regina, SK, S4P 2W1. **MANAGEMENT OF INDUSTRIAL/URBAN EFFLUENT DISCHARGES IN SASKATCHEWAN.**

Treatment and discharge of effluents from urban and industrial sources in Saskatchewan is controlled by three major legislative instruments. The main legislative controls are The Environmental Management and Protection Act, The Water Pollution Control and Waterworks Regulations, and The Saskatchewan Water Corporation Act. Saskatchewan Environment and Public Safety delivers these controls through its Water Quality Branch, which is mandated to protect and enhance Saskatchewan water quality. The Branch uses an "Environmental Management Model" to administer the legislation. The model embodies five main points: environmental quality objectives, works standards and emission limits, construction and operating licences, monitoring and inspections, review, and updating and enforcement. The Saskatchewan Surface Water Quality Objectives address water quality management policy, effluent discharge mixing zones in receiving waters, and parameter- and use-specific water quality objectives. The application of the legislation and policies encompasses 614 works in the province, of which 506 are municipal, including 12 cities. Of the 108 non-municipal works, 24 are industrial sites, representing 18 different types of industry.

Scrimgeour, G. J.[1], J. M. Culp[2], M. L. Bothwell[2], F. J. Wrona[1]. [1]Department of Biological Sciences, University of Calgary, Calgary, AB; [2]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5. **ALGAL PATCH DEPLETION MECHANISMS IN LOTIC ECOSYSTEMS: IMPORTANCE OF CONSUMPTIVE AND NON-CONSUMPTIVE LOSSES IN MAYFLY-DIATOM SYSTEMS.**

We forward four models of algal patch depletion based on the combined effects of a type II functional response consumptive model and four possible forms of non-consumptive loss. We tested these models in laboratory feeding trials by examining the relative importance of consumptive and non-consumptive removal of the diatom, Navicula, by three common mayfly grazers, Baetis tricaudatus, Paraleptophlebia heteronea and Ephemerella aurivilli. These trials were conducted in plexiglas streams that contained substrates with one of five biomass levels (0.11, 0.24, 0.43, 0.65, 0.92 mg/cm^2 dry weight) of the diatom prey. After each 1 h feeding trial, consumption was measured, and the remaining algae scraped from the substrates so non-consumption and total patch depletion could be determined. Consumption by all three species followed a type II functional response, mayflies were capable of grazing diatom layers of extremely low biomass (0.11 mg/cm^2) and each reached an asymptotic feeding rate when diatom biomass ranged from 0.24-0.43 mg/cm^2. When diatom biomass

Sauer, M. T.[1] [1]Limnologist/Water Quality Program Manager, North Dakota State Department of Health and Consolidated Laboratories, 1200 Missouri Avenue, P.O. Box 5520, Bismarck, ND 58502-5520. **LAKE MANAGEMENT IN THE STATE OF NORTH DAKOTA.**

North Dakota has 216 lakes and reservoirs capable of supporting a sport fishery. Reducing cultural eutrophication resulting from agricultural nonpoint loading of nutrients and sediments are major management goals. Several in-lake restoration techniques and land use management plans have been implemented.

Schryer, R.[1] [1]Biology Department, University of Saskatchevan, Saskatoon, SK, S7N 0W0. **THE REPRODUCTIVE SUCCESS OF WALLEYE (*STIZOSTEDION VITREUM*) IN BOTH SALINE AND NON-SALINE ENVIRONMENTS.**

Few teleosts are able to reproduce in the conditions presented by inland saline waters. This project examined the lack of reproductive success of an introduced walleye population in a sub-saline lake. This lake, Fife Lake, is located in south-central Saskatchevan and is characterized by salinity ranging from 4000 to 6000 uhmos. Histological methods were used to determine the effects of salinity on the gonads of these fish. Samples were taken throughout the year and compared with tissues taken from a lake (Buffalo Pound Lake) where a successfully reproducing walleye population exists. The development of fertilized eggs, along with the quality of the gametes, were also examined.

The ovaries of Fife Lake females were characterized by severe haemorrhaging, large masses of dead, adhered eggs, and a lack of final maturation. Testes were also plagued by haemorrhaging (blood filled semen) and necrotic tissue. Spermiation did not occur and consequently very little spermatozoa could be released. The spermatozoa produced by these males displayed poor motility and vigour and 75% had little or no tail.

Very poor fertilization rates of eggs and survival of developing embryos were observed. Only 0.01% of eggs examined hatched and all fry perished before reaching the exogenous feeding stage. Developmental anomalies included the lack of haemoglobin and/or erythrocytes, severe edema, and lack or deformed head, body, and tail.

context of stability theory. Intermittency can be divided into three phases: phase I represents water loss from the stream; phase II is the period of water absence, and phase III commences with the rewetting of the stream. Biotic responses can be similarly categorized by modifying traditional ideas of stability: resistance I refers to resistance to water loss and ecosystem shrinkage, resistance II is the ability to withstand the absence of water, and resistance III is the ability to maintain viability upon rewetting. Resilience is the subsequent rate of recovery after rewetting of the previously dry stream. This approach provides a theoretical framework within which comparisons between sites and/or times are easily made. Conversely, studies of intermittency may provide general insights into ideas of disturbance and stability of ecosystems.

Stephens, D. W.[1] and B. Waddell[2]. [1]U.S. Geological Survey, Salt Lake City, Utah; [2]Fish and Wildlife Services, Salt Lake City, Utah.
SELENIUM CONTAMINATION OF WATERFOWL AREAS IN UTAH AND OPTIONS FOR MANAGEMENT.

Selenium, an element required in trace quantities for animal health, can cause problems for livestock, wildlife and humans when ingested in larger-than-required concentrations. It is present in many sedimentary deposits and in arid, alkaline soils typical of the western United States can be mobilized by irrigation and reach hazardous concentrations in drainage water. If water containing selenium enters a wetland or pond, biological processes can increase the concentration within wildlife and cause deformities and reduced reproduction. Published studies indicate that adverse reproductive effects may occur in wildlife when concentrations of selenium in water are as small as 2 to 5 micrograms per liter. Within the Uinta Basin of Utah, large concentrations of selenium have been found in water and wildlife at Stewart Lake Waterfowl Management Area and at Ouray National Wildlife Refuge. Options for remedial action for contaminated areas involve changes in management of water, drainage, land-use, wildlife and possible application of waste-water treatment processes. Management options under investigation at Ouray National Wildlife Refuge consist of reducing canal seepage that recharges a shallow aquifer containing seleniferous material and the dilution of water in contaminated ponds.

was low (0.11 mg/cm^2), the amount of algae ingested accounted from 27%-75% of total depletion of algal patches. Above this level, non-consumptive foraging related losses increased. Thus, depletion of diatom patches was non-linear and positively related with diatom biomass due to the disproportionate increase in non-consumptive losses combined with the type II functional response consumptive model (Case 4). this disproportionate increase in non-consumptive loss may result from (i) a passive process attributable to mechanical limitations of the feeding apparatus or (ii) an active selection process during foraging. Regardless of the mechanism, our experiments indicate the importance of considering algal patch depletion by mayfly grazers as a dual product of consumptive and non-consumptive foraging processes.

Snyder, R. A.[1,2], R. D. Robarts[1] and D. E. Caldwell[2]. [1]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5; [2]Department of Applied Microbiology, University of Saskatchevan, Saskatoon, SK, S7N 0W0. **MEASURING HETEROTROPHIC BACTERIAL PRODUCTION: VALIDATION OF THE ^{3}H THYMIDINE INCORPORATION METHOD USING CHEMOSTAT CULTURES AND COMPUTER ASSISTED IMAGE ANALYSIS.**

The measurement of the rate of DNA synthesis in heterotrophic bacteria by the incorporation of ^{3}H thymidine has been widely used as a measure of microbial growth and activity in environmental samples. However, there has been some question of the consistency and effectiveness of this technique stemming from conflicting reports in the literature. A great deal of the controversy concerns the conversion factors used, that is the ratio of thymidine incorporation to bacterial production. We have attempted to define the variability in the use of this assay with single species chemostat cultures of varying generation times. Chemostat cultures at 18°C on a standardized medium allow the researcher to set growth and production rates by the flow rate through the culture vessel. With these variables set, we have measured the incorporation of thymidine, and expressed conversion factors by cell number and by bacterial biomass as determined with computer assisted image analysis. Conversion factors were found to vary between the particular species used, and also with the generation time within species. Conclusions based on our experimental results will be discussed.

Stanley, E. H.[1] and S. G. Fisher[1]. [1]Department of Zoology, Arizona State University, Tempe, AZ 85287. **INTERMITTENCY, DISTURBANCE, AND STABILITY IN STREAM ECOSYSTEMS.**

Intermittent streams are common, particularly in arid and semi-arid regions of the world, yet they have received little attention from researchers and therefore are poorly understood. We propose a conceptual framework in which intermittency can be studied by considering drying as a disturbance and examining its effects in the

Thomas, P.[1], J. Byrne and R. J. Rogerson. [1]Water Resources Institute, University of Lethbridge, 4401 University Drive, Lethbridge, AB, T1K 3M4. **POTENTIAL IMPACT ASSESSMENT OF NITRATE POLLUTION ON SURFACE AND GROUNDWATER SYSTEMS FROM INTENSIVE ANIMAL HUSBANDRY OPERATIONS.**

Intensive livestock feeding operations in southern Alberta were perceived to be causing a potential for serious nitrate pollution in surface and groundwater systems. Minimal regulation to date has allowed the industry to expand rapidly, with no environmental impact assessments. This study examines the local and regional influence of livestock operations on the area's surface and groundwater network.

A GIS package, SPANS, has been utilized to create a series of maps defining areas within the County of Lethbridge with a serious pollution risk. The analysis uses overlays of soil, topographic and hydrologic data to establish criteria defining these areas. Existing feeding operations were simulated with a point source, exponential decline pollution potential on both surface and ground water systems. Topographical data is being utilized in conjunction with surface water drainage locations to modify the concentric shape produced by the exponential function. Regional groundwater flow patterns were applied in the same fashion to estimate the skew in the model for subsurface concerns. The risk and impact maps are being developed from overlays of the impacts associated with multiple operations. The final output maps may be utilized by the municipal government in planning and regulation of livestock operations in order to minimize pollution hazards on sensitive aquatic ecosystems.

Thoms, M. C.[1] and K. F. Walker. [1]River Murray Laboratory, University of Adelaide, Box 498 Adelaide, Australia 5001. **SEDIMENT TRANSPORT IN THE RIVER MURRAY, AUSTRALIA.**

Analyses of sediment transport behaviour in the highly regulated River Murray, Australia, indicate the impact of water management practices on the river system. Data from eight stations between 1974 and 1989 demonstrate the majority of the sediment load was transported during the summer months (October-March). Sixty-eight percent of the total sediment load was transported during these flows; this was an effect of higher summer suspended sediment concentrations combined with the maintenance of artificially high flows. Discharges were near channel capacity for most of the summer months in order to meet irrigation demands further downstream.

A sediment budget for this reach of the Murray highlights two important features of sediment transport in this system. The trap efficiences of the two impoundments in this reach were high. Over 50 percent (1 m tonnes) of the total sediment load was deposited in the

Stolte, W. J.[1], S. L. Barbour[1] and R. G. Eilers[2]. [1]Department of Civil Engineering, University of Saskatchevan, Saskatoon, SK, S7N OWO; [2]Canada-Manitoba Soil Survey, University of Manitoba, Winnipeg, MB, R3T 2N2. **IMPACT OF VEGETATION CHANGES IN SALINITY NEAR PRAIRIE WETLANDS.**

Wetlands on the Canadian prairies are in jeopardy. The recent drought has left wetlands as one of the fev locations vhere agricultural productivity is high. This has led to drainage, and/or the clearing of vegetation in the areas immediately adjacent to the wetlands. Through clearing, woody vegetation such as villovs and poplars is replaced by cereal grains. The annual cereal grains tend to have shallover root systems than the perennial woody vegetation. This change in vegetation and consequently, rooting depth, will have some impact on the evapotranspiration regime and also on salinity redistribution in the near-slough regions. This paper will deal with the results of modelling the moisture movement around wetlands and hov that is impacted by the change in vegetation. Specifically, it will be shown that replacement of the deeply rooted plant species with cereal grains will have the effect of concentrating the soil salinity nearer the surface where it will have a negative impact on the soil quality. The paper will demonstrate that relatively nonsaline soils can become salinized through this effect and that salinity migration from underlying aquifers is not required to produce the ubiquitous saline rings around prairie sloughs.

Tayab, M. R.[1] [1]Department of Chemistry, Brunel University, Uxbridge, Middx. U.K. **CONTAMINATION OF SEDIMENTS BY HEAVY METALS.**

One of the most important processes controlling the transport of heavy metals is adsorption onto solid surfaces. In natural aquatic systems metals are partitioned between the dissolved and particulate phases and only the fraction associated with the solid surface is easily exchangeable with the aqueous phase. It is proposed that adsorptive interactions with clays and oxide surfaces may exert the major control on dissolved metal concentrations in marine, freshvater and soil environment. It is necessary to knov the changing conditions will effect metal adsorption in order to intelligently manage enterprises such as dumping dredge spoils into an environment different from the designing sites or controlling effluents from industrial sources.

Wallace, R. R.[1] [1]President, Dominion Ecological Consulting, Ltd., Calgary, AB, T2P 0M2. **ALLOCATIVE DECISIONS FOR AQUATIC ECOSYSTEMS IN WESTERN CANADA.**

In the past several years, there has been an accelerating, increasing demand on western Canadian water resources. These demands have originated from both industrial and domestic sources and have been the centre of enhanced attention from the public and public interest groups. Unquestionably, there will be more, not less, attention paid to this subject as our diminishing resources are increasingly challenged by consumptive demands.

The process of deciding who, or what, users of those waters will be licensed by government is becoming ever-more complex. Legal processes are growing in importance in both enforcement and compliance aspects of water management and the public is demanding a heightened role in consultations about the water allocation process.

The challenge of the 21st century will be to develop systems which account for public concerns about water management and conservation while alloving for the orderly development of economic activities. These systems are only poorly understood nov and, it is predicted, will become a major source of public and political debate. Recent controversies in Alberta, for instance, over water allocation for effluent loadings and other consumptive purposes for the hydrocarbon industry are, it is argued, just the beginning of a significant shift in the public avareness.

Scientists, water managers and government representatives will have to develop more efficient, and timely, methods for integration of all the aspects associated with water management while, at the same time, enhancing the methods and types of consultation with the public-at-interest.

There are several models which have been attempted in Alberta in the recent past, which may assist in guiding policy-makers and conservationists alike, toward nev approaches to decision making and contractural procedures for allocative uses of vater resources. These are discussed with an emphasis on using case-studies to assist in the evolution of nev policies and procedures.

Veagle, K. V.[1] [1]Manager, Water Quality Management Section, Sask. Environment and Public Safety, 3085 Albert St., Regina, SK, S4S 0B1. **A TROPHIC STATE MODEL FOR LAKE DIEFENBAKER.**

A model to predict the trophic state of Lake Diefenbaker vas developed. The model took into account loadings from the South Saskatchevan River, the atmosphere, and the lands surrounding the lake. The mass balance of phosphorus entering and leaving the lake indicated that there vas little or no regeneration of phosphorus from the lake sediments. The model vas based on the folloving list of

reservoirs. Channel erosion was the dominant sediment source especially in reaches below the impoundments, contributing to over 60 percent of the sediment load. This sediment source area was particularly important during irrigation flows.

van der Kamp, G.[1] [1]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5. **INTERACTIONS BETWEEN GROUNDWATER AND PRAIRIE WETLANDS.**

In the semi-arid glaciated northern plains wetlands constitute an important hydrological link between groundwater and surface water. A conceptual framework can be developed for the water balance and salinity of prairie wetlands in relation to groundwater flow, based on the concepts of depression-focussed groundwater recharge and wetland-focussed discharge. The interactions between groundwater and a particular wetland depend strongly on the hydrogeological and landscape setting of the wetland. In southern Saskatchewan the artificial drainage and creation of wetlands and depressions has not had an identifiable impact on groundwater levels, but the margins of artificial wetlands are commonly subject to salinization.

Vaux, P. D.[1], L. J. Paulson[1] and R. P. Axler[2]. [1]Lake Mead Limnological Research Centre, University of Nevada, 4505 Maryland Parkway, Las Vegas, NV 89154; [2]Natural Resources Research Institute, Duluth, Minnesota. **ARTIFICIAL FERTILIZATION OF A LARGE DESERT RESERVOIR: TROPHIC LEVEL INTERACTIONS AND WATER QUALITY ISSUES.**

Lake Mead is a 660 km^2 surface area reservoir on the Colorado River that supports sports fisheries valued in excess of $70 million per year. Despite their economic importance, these fisheries are currently suffering from two problems. The largemouth bass harvest has declined dramatically since the mid-1960's, and the condition of striped bass has decreased to a point where emaciated fish are common in the population. Inadequate forage (threadfin shad) is thought to be a principal factor in these declines. One reason for this is hypothesized to be reduced reservoir productivity following upstream impoundment of the Colorado River and a consequent reduction in nutrient loading to Lake Mead. To investigate this hypothesis, a 10,000 hectare area of Lake Mead was fertilized over a three-year period with liquid ammonium polyphosphate. Impacts of enhanced productivity at the base of the food chain were clearly observed in some components of the zooplankton community and data suggest that there may also have been a direct effect on shad year class strength. Various water supply agencies exhibited considerable interest in the potential water quality impacts of this experiment, particularly from the perspectives of taste and odor, and trihalomethane precursor formation potentials.

Winter, T. C.[1] [1]U.S. Geological Survey, Mail Stop 413, Denver Federal Centre, Lakewood, CO 80225. **A FRAMEWORK FOR LONG-TERM HYDROLOGIC STUDIES OF WETLANDS.**

The increasing awareness of the complexity of the functions of wetlands and associated aquatic resources indicates the need for multidisciplinary research on these systems. Furthermore, because studies of isolated systems cannot address the universal applicability of results, the studies need to be designed to facilitate intersite comparisons. This is necessary so processes common to all wetlands can be distinguished from those unique to particular landscapes and climatic settings. It has been suggested that wetlands occur in particular types of physiographic and climatic settings in the context of a generalized landscape. The generalized landscape, defined as an upland adjacent to a lowland separated by a steeper break in slope, can have two major surface textures, smooth or hummocky. This paper extends the idea of a generalized landscape for wetlands by suggesting actual landscapes within North America, based on physiography and climate, that are proposed high-priority settings in which wetland research could be focused. The seven principal physiographic settings are: (1) terraces and scarps within coastal lowlands, including tidal flats, (2) riverine valleys, including the contiguous upland and river, (3) steep slopes with contiguous narrow lowlands, (4) large depressions with contiguous extensive flats, (5) morainal kettles, (6) dune fields, and (7) sink hole and other depressions. The first four are assumed to have smooth surfaces with uniform slopes, and the last three have hummocky surfaces. The climatic criteria are based on gradients between cold-warm, wet-dry extremes.

Wobeser, G.[1] [1]Department of Veterinary Pathology, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, SK, S7N 0W0. **SALINITY OF PRAIRIE WETLANDS IN RELATION TO WATERFOWL DISEASE.**

Wild waterfowl use saline wetlands for breeding, feeding and roosting, but the effects of salinity, of the type found in the prairie pothole region, on waterfowl has received little attention. Three problems have been identified in the prairie provinces. Experimental trials and field observation indicate that saline water with conductivity of about 20,000 umho/cm is lethal to ducklings. Water with conductivity in the range between 5000 and 20,000 umho/cm causes sub-lethal effects including growth depression. Wetlands with water of this type have been "improved" for duckling production. Geese and ducks using hypersaline wetlands for roosting and staging have died as a result of salt encrustation when the water became supersaturated as a result of cooling. "Necrotizing enteritis", a fatal intestinal disease of geese has been recognized each autumn since 1983; all reported outbreaks have occurred on saline wetlands, but the nature of the association between salinity and the disease is unknown at present.

variables: FLOW; AQUATIC TOTAL PHOSPHORUS LOAD; THE EFFECTIVE DRAINAGE BASIN AND EXPORT COEFFICIENTS OF THE LAND USES; ATMOSPHERIC INPUT COEFFICIENT. The model showed that major changes in the trophic state of Lake Diefenbaker would most likely originate from changes in the inputs from the South Saskatchewan R. or major inter-basin transfers. The mass balance study showed that Lake Diefenbaker was a phosphorus sink and that significant changes to the trophic status of the lakes could occur if the lake became anoxic. This would result in the release of significant quantities of sediment phosphorus.

In all the lake areas except Douglas arm the aquatic loadings contributed from 73-94% of the total phosphorus loading. In Douglas arm aquatic loadings were from 14-18%, and the land loadings contributed from 77-80% of the total phosphorus loading. The trophic indicator (total phosphorus concentration, chlorophyll 'a' concentration, secchi depth) with the highest predictive accuracy for the study was chlorophyll 'a' concentration.

Using the OECD criteria it was concluded that in 1987 all the areas of the lake except Danielson were mesotrophic and Danielson was oligotrophic.

It was concluded that no water quality objective for phosphorus in the South Saskatchewan River upstream of Lake Diefenbaker was appropriate at this time. This conclusion was based on the fact that most of the phosphorus entering the lake via the South Saskatchewan River was the product of natural erosion and could not be controlled. If a water quality objective was developed in the future it should concentrate on dissolved phosphorus as opposed to total phosphorus. Dissolved phosphorus is more commonly caused by anthropogenic activity.

Using the upper mesotrophic level for chlorophyll 'a' of 0.008 mg/l and back calculating for total phosphorus a water quality objective for total phosphorus in the lake was calculated to be 0.06.

Webb, D. J.[1] and E. E. Prepas[1]. [1]Department of Zoology, University of Alberta, Edmonton, AB, T6G 2E9. **THE RELATIONSHIP BETWEEN PHYTOPLANKTON DYNAMICS, NUTRIENTS TEMPERATURE, LIGHT AND OXYGENATION IN AMISK LAKE, ALBERTA.**

Chlorophyll a concentration (Chla) can vary spatially and temporally within a lake. We studied the changes in Chla in Amisk Lake (a deep, naturally-eutrophic lake in north-central Alberta) temporally (May 1988 to February 1990) and spatially (six depths at six sites) to determine the extent of temporal and spatial heterogeneity in Chla. Results indicate significant variation through time at any specific depth ($P<0.001$), but not between stations ($P>0.25$). Further analyses will determine the degree of correlation between Chla variation and nutrient concentrations, temperature, light, phytoplankton species and abundance, and hypolimnetic oxygen injection. These results will be discussed at the conference.

AQUATIC ECOSYSTEMS IN SEMI-ARID REGIONS
AUGUST 27-30, 1990
SASKATOON, SASKATCHEWAN

ABSTRACTS OF POSTER PAPERS

Arndt, J. L.[1] and J. L. Richardson[1]. Department of Soil Science, North Dakota State University, P.O. Box 5575, Fargo, ND 58105. **CARBONATE AND GYPSUM CHEMISTRY IN SATURATED, NEUTRAL pH SOIL ENVIRONMENTS.**

The equilibrium geochemistry of CO_2-calcite-gypsum-water systems is examined. These systems are particularly important for understanding hydric soils of the Northern Plains because calcite ($CaCO_3$) and gypsum ($CaSO_4 \cdot 2H_2O$) often exist in conjunction with saturated conditions under relatively high CO_2 partial pressures (Pco_2). As such, geochemical equilibrium relationships characteristic of these systems strongly influence pH, soil and solution chemistry, and profile morphology in wetland soils. Placed in the context of CO_2-calcite-gypsum-water systems, bacterially mediated aerobic and anaerobic sulfur respiration may provide insights to carbon mineralization and carbon fluxes in wetlands. An examination of the CO_2-calcite-gypsum-carbohydrate-water system in Northern Prairie wetlands indicates that half of the C mineralized due to sulfate reduction may flow through a calcite reservoir with possibly lengthy residence times. Thus calcite can act as a temporary solid-phase inorganic sink for mineralized carbon. Whether or not this sink becomes permanent will depend upon fluxes of reactive constituents into and out of the system, charge balance considerations, cation exchange, and the direction and intensity of saturated/unsaturated flow and the resultant redox fluxes.

László F.[1] [1]Zoological Department, Hungarian Natural History Museum, Baross u. 13, H-1088 Budapest, Hungary. **THE MICROCRUSTACEAN COMMUNITIES OF THE SODIC WATERS IN THE CARPATHIAN BASIN.**

The small, temporary sodic pans are very characteristic water bodies in the Carpathian Basin. they are highly alkaline, sodium and carbonate and/or bicarbonate are the dominant ions. Studies in the microfauna started about 100 years ago. Some 120 microcrustacean (Branchiopoda, Copepoda and Ostracoda) species have been recorded here, six cladocerans and two copepods occurring most frequently. Presence-absence data from several Hungarian and Austrian pans were analysed by DCA and the first two axes were related to environmental parameters. It was found that besides alkalinity and salinity ion composition plays an important role in determining the structure of zooplankton communities.

Calvo, J. F.[1], M. A. Esteve, A. Giménez, R. Gómez, G. González, V. Hernández, A. Millán, M. Ortega, L. Ramírez-Díaz, F. Robledano, M. L. Suárez, J. Velasco y M. R. Vidal-Abarca. [1]Dept. de Biologia Animal y Ecolgia, Univ. de Murcia, Murcia Spain 30100. **CONSERVATION OF WETLANDS IN A REGIONAL TERRITORIAL FRAMEWORK. JUSTIFICATION AND METHODOLOGICAL PROPOSALS.**

Wetlands are remarkable events in the landscape of arid regions holding important naturalistic, cultural and economic values, and acting as regulators of landscape dynamics.

Best developed wetland conservation policies refer to large territorial frameworks in which small wetlands are obviously neglected, in spite of their outstanding relevance in a regional context.

The conservation of these scattered (in time and space) landscape items, requires strategies radically different from those used at an international scale, based primarily in biological criteria like rarity. In this paper, a methodology based in the adoption of wetland complexes as the basic management unit, and in the use of comprehensive criteria like representativity, is proposed.

This scheme has been applied to the Murcia Region (SE Spain) where 74 wetlands have been inventoried (19.261 Ha) belonging to 11 types. Five functional complexes, comprising a representative portion of ten of these types (95% of their area) have been defined.

Ortega Rivas, M.[1], R. Gómez[1], M. L. Suárez[1] M. R. Vidal-Abarca[1], J. F. Calvo[1], J. A. Palazón[1] and L. Ramírez-Díaz[1]. [1]Departmento de Biologia Animal y Ecologia, Universidad de Murcia, Spain. **SUPERFICIAL HIDROCHEMICAL CHARACTERIZATION AND TYPIFICATION OF THE PONDS IN A SEMIARID REGION THE S.E. OF SPAIN (MURCIA).**

A catalogue of the vetlands of the Murcia region has been made. This is a region of semiarid environmental characteristics hence this type of ecosystems present a very diverse typology.

One of the most singular types are the ponds. The results of the physico-chemical water analysis allov to make a first classification in relation to its ionic content.

By means of the multivariate analysis of classification and ordenation, the typification of these ecosystems is made as a function of the physico-chemical parameters and the physical environment, which reflect a geographic distribution in a mosaic responding to the typical antropic and environmental factors of the semiarid regions of the southeastern Spain.

Rosenberry, D. O.[1] [1]U.S. Geological Survey, MS 413, Denver Federal Centre, Lakewood, CO 80225. **GROUND-WATER RECHARGE FOCUSED ADJACENT TO A WETLAND IN THE COTTONWOOD LAKE AREA, NORTH DAKOTA, USA.**

Five water-table wells located across a 50-meter wide isthmus between a seasonal wetland and a semipermanent wetland were instrumented with continuous recorders to measure fluctuations of the water table between the two wetlands. During the early summer of 1989 a water-table trough under the isthmus indicated seepage from the semipermanent wetland to ground water. The topographically higher seasonal wetland was dry the entire year. After 120 mm of rainfall in August, a water-table mound developed which reversed the flow direction, causing ground water to flow into the semipermanent wetland. This water-table mound reached a maximum height above the wetland of 0.55 meter, 18 meters from the edge of the semipermanent wetland. During 20 days of redistribution following rainfall, the apex of the water-table mound decreased in elevation and moved away from the wetland. The data indicate that wetland-ground water interaction in the transition zone between uplands and wetlands is complex, being a dynamic interplay of focused recharge, evapotranspiration, and perhaps other processes.

Suárez, M. L.[1], C. Montes[2], L. Ramirez-Diaz[1], M. R. Vidal-Abarca[1]. [1]Departmento de Biologia Animal y Ecologia, Universidad de Murcia, Spain; [2]Departmento de Ecologia, Universidad Autónoma de Madrid, Spain. **SPATIAL HIDROCHEMICAL HETEROGENEITY OF THE WATER IN A SEMIARID CHARACTERISTICS BASIN OF THE SOUTH-EAST SPAIN (MULA RIVER BASIN).**

The physico-chemical analyses of 69 water samples distributed in watercourses of the Mula River Basin, have been used to detect the relationships between different environmental and antropic processes that occur in the semiarid basins.

The complex relationships between underwaters and watercourses in semiarid basins can explain both the physico-chemical composition and the quality of water flowing through the streams.

Using different statistical analyses a hydrochemical spatial pattern is detected.

Sushil[1] [1]Field Station, Zoology Department, University of Jodhpur, Jodhpur 342 001, India. **OXYGEN - TEMPERATURE INFLUENCE ON LAKE RANISAGAR.**

The long summer days and clear skies in semi-arid regions gives rise to stratification in lake Ranisagar. The lake is most unstable in December (winter) and moves towards stability through the summer and is most stable in June - July. Thereafter the erosion of stratification continues through monsoon and is completely eroded in winter. Oxygen closely follows the temperature and shows orthograde distribution and inverse clinograde distribution in co-occourance with the temperature orthograde and clinograde curves. Despite the low winter temperature, DO was very low in both the years of the study.

Thornton, J. A.[1] and W. Rast. [1]Co-operative Extension Service, College of Natural Resources, University of Wisconsin - Stevens Point, Stevens Point, Wisconsin 54481. **A COMPARISON OF REGRESSION CURVES GENERATED FROM SEMI-ARID MAN-MADE LAKES AND THE OECD STUDY: IMPLICATIONS FOR RESOURCE MANAGEMENT.**

Selected morphological and limnological data on 201 man-made lakes in the semi-arid zones of the world were compiled from the literature. After some preliminary screening these data were plotted on axes previously defined by the OECD in their study of predominantly temperate lake systems. Such scatterplots highlight real differences in eutrophication response between these climatic zones. Generally, the OECD phosphorus-chlorophyll and phosphorus concentration-phosphorus loading relationships were found to apply to semi-arid lakes suggesting the essential sameness of the underlying biogeochemistry of the organisms involved and their medium. Relationships between secchi disc transparency and both phosphorus and chlorophyll concentrations do show significant variations, underscoring the relatively high level of inorganic turbidity present in many semi-arid waterbodies. (Such relationships, when viewed in conjunction with the phosphorus-chlorophyll relationship, support the hypothesis that turbidity compresses the euphotic zone rather than diminishing algal biomass.) The presence of inorganic turbidity is borne out by the lower orthophosphate : total phosphorus ratio observed in semi-arid zone lakes. finally, the N:P ratio in semi-arid waterbodies is typically lower than in corresponding temperate lakes leading to blue-green algal dominance in many eutrophic lakes. The implications of such comparisons for resource management are in terms of the relevance of common eutrophication threshold values rather than in terms of the fundamental processes occurring in the waterbodies.